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Public Procurement Proximity Network

An Economic Complexity Application

Lia Machado Ribeiro

Project presented as a requirement to obtain the Master's degree in Information Management

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ABSTRACT

One fundamental question in one's economy development, is why some areas perform better than others? This document aims to map the Portuguese service proximity and relatedness from the private sector perspective. We analyze services offered by private entities contracted by the Portuguese government and describe their patterns to better understand how this space is structured.

This thesis explores how services interact inside the Portuguese procurement space and lastly, if their closeness benefits their market share. It integrates evolutionary economic foundations with Portuguese data to create a unique model that can then be further scrutinized. It contains a holistic approach to further understand Portugal's reality and helps sharpen what is yet undiscovered. It propositions over an optimal data resolution selection and sheds some light on future strategies to policy makers on the usage of vocabulary codes.

KEYWORDS

Services; Diversity; Network analysis; **RELATEDNESS**; proximity; **Public Procurement**; Clustering; Revealed Compared advantage, **Portuguese Procurement Proximity Network(3PN)**

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LIST OF ABBREVIATIONS AND ACRONYMS

CPV	Common procurement vocabulary Codes
IMPIC	Instituto dos Mercados Públicos, do Imobiliário e da Construção, I.P.
NIF	Portuguese fiscal Number("Número de identificação fiscal")
PCC	Portuguese Public Contracts Code
RCA	Revealed comparative advantage
VAT	Value added tax
3PN	Procurement Procurement Proximity Network

I. INTRODUCTION

There is a growing interest in studying the pathways for knowledge relatedness and diversification in many areas of our society. Examples range from how countries, institutions, and cities (Hidalgo C. A., 2021) acquire the know-how to develop new industrial capabilities, but also how individuals learn new occupations. Past works have used data and network science methods to map relatedness of activities that such agents can develop. This signals a successful approach in describing the natural tendency of economies, regions, institutions, and individuals to diversify. Furthermore, it is said that the productive structure of a given country strongly determines its future economic growth, diversification and lastly income inequality (Dominik, Mayra, & L. Pinheiro, 2019; Hidalgo, et al., 2017).

Economic developments are interconnected in such ways that countries are more likely to develop new economic activities that are similar to the ones they already have in-house (Hidalgo, et al., 2017). To Adam Smith, when people and organizations diversify their activities, the economic growth also increases giving the sense that these two are correlated, in other words, the number of individual activities and the complexity that emerges from their relationships is directly correlated to the development of one's economy (Hidalgo & Hausmann, 2009).

Some argue that public service demand is a major source of innovation that has a lot of potential to improve service delivery and generate synergies and benefits from associated spillovers. (Edler & Georghiou, 2007)Previous studies have concluded that over time public procurement has triggered innovation waves, surpassing R&D initiatives and that procurement can create new pioneer markets and innovation-intensive services (Kok & al., 2004). Furthermore innovation dynamics mostly depend on the scale and characteristics of demand and that these are determinant for the competitiveness of a given location (Edler & Georghiou, 2007).

The rationale under public procurement to trigger innovation can be seen in different levels. It represents domestic demand which fosters innovation and is a prime source of enhancing local enterprises competitiveness, and lastly it has the potential to improve public infrastructures and public services in a broader sense (Edler & Georghiou, 2007).This infatuates the idea that supply chains from private organizations service offerings should work closely with public institutions to benefit ones country, region or municipality that procures, to create spill overs in the global markets that benefits all economic agents (Edler & Georghiou, 2007).

Public administration and other entities that operate under specific non-competitive conditions (e.g. water, energy, public transportation or even postal services) use procurements to purchase services and goods. All procurements with medium/high range price must be granted under concurrent procedures defined by the Portuguese national laws, except for some very specific cases.

In August 2017, the Portuguese law (Decreto-Lei n. º 111-B/2017) has been republished to accommodate changes into the current regulation of Public Contracts code (CCP). The 'Portal BASE', centralizes information regarding the public contracts, under the management responsibility of IMPIC and provides important information about the execution of public contracts subject to the CCP. The information found on these datasets, are related to services offered by Portuguese private companies to the public sector.

It also provides information on published announcements related to the need for creating public contracts, and to contracts subjected to the parts II and III of the CCP, which include accurate and complete disclosure of goods, services or work that should be carried during the contract lifecycle, the overall price, the contractor's name, remaining competitors and the contract identified challenges. These datasets guarantee a free procurement market and to some extent allow citizens to supervise both private companies and politicians actions on public money expenditure (Rodríguez, Montequín, Fernández, & Balsera, 2019).

The type of government procedures inside the concurrent procedures varies in many ways of performing business with private organizations. One of the most commonly used in Portugal is known as open call which dictates that anyone can present a complete proposal to win public tenders.

Normally, the law mandates that the procuring authority issues public tenders if the value of the procurement exceeds a certain threshold. In Portugal, the government procurement is directed by the "Código dos Contratos Públicos" or Public Contracts Code (PCC). We will extract and process data available from BASE portal which covers the services sold by private companies to the public sector in Portugal to analyze the relatedness between services, which are encoded by the CPV that companies sell/perform. We'll use these datasets as the best proxy and hinging in the fact that these activities with the public sector have a considerable weight in the Portuguese Economy.

My proposal is to develop a view of development and economic growth using network science methods to infer how Portuguese private companies relate their service portfolio, through the analyses of traded services in a network where entities are bound to the offered services by the network characterization.

II. LITERATURE REVIEW

In this work we focus our attention to the Portuguese public procurement market, in particular to the service providers and their offerings to the public sector. We will use the available data as a proxy for the activity of private companies and explore the relatedness between services provided and how this condition their ability to relate their portfolio of services.

1. PORTUGAL AND PUBLIC PROCUREMENT

Governments around the world purchase goods and services in order to fulfill their needs and strategic initiatives. Government expenditure's has grew enormously as per the results of spending in areas like social protection, education and healthcare. This tendency is more noticeable in high-income countries (Ortiz-Ospina & Roser, 2019) has they deeply rely on private sector in order to produce services and goods that the public sector cannot develop. They procure private company's services to govern city or country's activities such maintenance and functioning of public infrastructures. (Curado, Damásio, Encarnação, Candia, & L. Pinheiro, 2021)

EU region governments operate under the same economic, social and sometimes political space with unpredictable and complex environments (OECD space).Public contracting represents a large volume of spending by governments, average of 12% in GDP by the OECD countries. (OECD, 2019) They play a major role directly binding it to the country economic strategy and should inspire efficiency and public trust (OECD, 2019)

Despite the subject importance, public procurement is a relatively under-researched area. To analyze data from the private organizations perspective becomes of upmost relevance in order to understand how the public Portuguese market evolves.

Portugal has been one of the EU state members registering the higher increase in public expenditure when compared to the percentage of GDP, between 1995 and 2011. (OECD, 2019) From 2011 onwards, it continues to register even higher values in areas like defense and public safety, health, education and social protection converging to the medium functional structure of EU region. This allowed for significant improvements in areas such as health (Braz & Cunha, 2012) A curious fact is that, until late September 2018, Portugal has registered a budgetary surplus of 1111 M€, equivalent to 0.7% of GDP generated in that period. In year 2016 almost 20% of total government expenditure was channeled through procurement, which represents 9, 01% of national income. (Braz & Cunha, 2012)

While discussing public procurement some different forms of purchase arise, which include tendering and contracting to build large infrastructural projects, but it goes beyond infrastructure, including the purchase of office supplies, the procurement for information technology services, social transfers and others. In Portugal, the total expenditure on government outsourcing is 7.5% of national income in 2016 (Ortiz-Ospina & Roser, 2019). The OECD defines a set of recommendations to be applied by all European countries that promote modernizing procurement systems by the use of a procurements life cycle interconnected with elements of strategic governance to increase integrity on such contracts. These directives require that all public tenders above certain contractual limits must be available beforehand (Mateus, Ferreira, & Carreira., 2010) and duly published in each countries official journals.

The Electronic Public Procurement Index in Portugal (ICPEP) was developed to control the percentage rate of public procurement procedures registered – has part of the Manchester commitment -through duly authorized electronic platforms. The total values in 2018 was approximately 82 % (IMPIC, 2020)which also reflects that carrying out direct award procedures through electronic platform is not a mandatory action (Roriz & Ministro, 2016).

The base portal - http://www.base.gov.pt/ - was created with the purpose of centralizing Portuguese public procurement data, public procurement related laws and lastly to disclose public information on the above subjects. This site must keep up to date information regarding the formation and execution of Portuguese public contracts, thus allowing for their tracking and monitoring (IMPIC, BASE contractos públicos online, s.d.). The data comprises information related to the final contract value, contracting and contracted/s entities, execution site, applicants, duration, closing date, CPV among others.

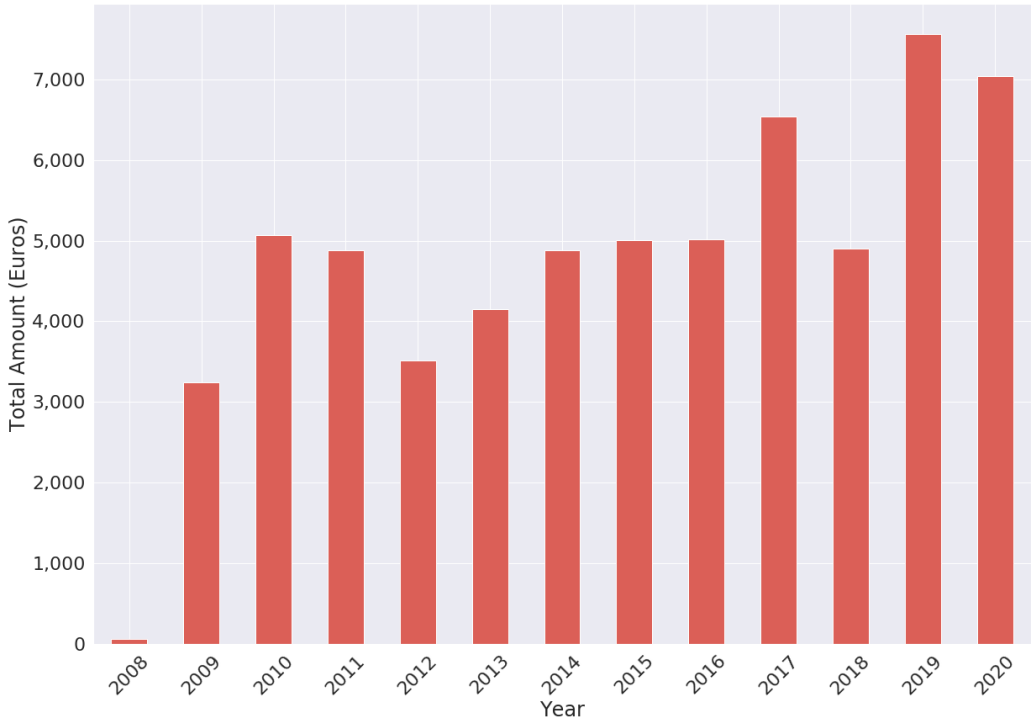

Figure 1 | **Yearly Contract amount distribution (€)** we observe the yearly contract amount variation and note a descending tendency for 2011, 2012 and 2018.This can be possible explained with austerity measures imposed on those periods which invariable led to less procurement contracts.

Figure 1, shows the distribution of the total amount of public contracts reported in 2008-2020 (*retrieved data in 21th of November 2019 and 5th April of 2021(year 2019 and 2020*), and validates that overall public procurement spending has increased - almost doubling their value from 2013 to 2019- , with minor setbacks in the years 2012 and 2018.

The raw data analyzed accounts for the total sum of 109721 uniquely identified entities which 9% relate to foreign or unidentified entities. The number of contract occurrences range from 1 to 1043 and their average is of 2.33 contracts held, which could be seen has a narrow distribution of contracts in the service space. From 1,048,576 total electronical reported contracts we denote that contracts distribution can be somehow ambiguous, due to duplications. Different regions report the same contract price values, this happens because shared contracts with several public institutions are also registered.

2. NETWORK SCIENCE

Major organizations like Google, Facebook or Twitter use network analysis in their base technology and business model. Examples range from mapping the world's social network or

the human genome project that was completed in 2001 and has a result offered a list of all human genes and their mappings/interactions to protein, metabolites and other cellular components, creating a molecular network (Barabási, 2016)

Perhaps, not surprisingly, network analysis is today an interdisciplinary field with many mature methodologies and applications on diversified areas that provide a common framework to study network systems and analyze their implications on the unfolding dynamical processes that govern them. Network science has its roots in graph theory but because it has an appeal for empirical studies and its focus on data, it can be distinguished from it.

Network science provide us with a common methodology to study some important networks and one in particular is of upmost interest for this thesis that is, the product space (Barabási, 2016). Some papers developed by Hidalgo have drowned structures that are critical to understand the national wide economic development, embodied by the services one country's provide and constraint the ease of transforming one's economy.

The seminal work by Hidalgo et al (Hidalgo et al., 2007) proposed the product space as a network that inspired the subject of this thesis and the use of network analysis methodology. His representation on how different products are related to one another suggests the notion of proximity and distance between them. For instance, oranges and lemons are more identical, when compared to oranges and copper wires. (Correia da Cunha & Braz, 2012)This structural perspective is relevant to occupations in urban economies as we will try to showcase that alike the product space network, the Portuguese service space also shares most of the behavioral characteristics and their evolvement, creating a new sense of evolution for the Portuguese region.

The Product Space (Hidalgo, Klinger, Barabási, & Hausmann, 2007) is a network that connects products in terms of the necessary knowledge and skills needed to produce them and demonstrates the probability of a country to export a product – node, representing an activity in the network - increases with the number of related services/products already present in that country/area. It builds a network that binds products with stronger connections - measured using density or weighted average of related activities. Hence, more distant products are less similar with weaker bonds. This network has helped to further understand and even predict why some countries undergo economic growth while others remain or lower their income and provides data visualizations of exportations performed by a given country.

Likewise it can be considered an approach that uses outcome-based measures to relate two services, and advocates that activities are similar once they require the same level of knowledge, technology, physical factors or a sort of combination of all, these are based on the conditional probability of a service a and b having a positive Revealed Comparative Advantage (RCA). A key objective for this master thesis is to understand how services offered by Portuguese private companies are related between them self's and if they defy this relatedness principle.

Service related contracts include all activities such as provision of consultancy, training or even cleaning services. (Curado, Damásio, Encarnação, Candia, & L. Pinheiro, 2021) Some differences can be found while comparing products and services, for instance, products tend to fill a customers need while a service points to build a relationship of trust and normally do not offer multiple formulations. Unlike products, services are known to be intangible – not having a physical presence (Kotler, 1983) - they cannot be touched although share similar attributes that can be studied and compared, hence, services can be studied in a symmetric way of correlation with products.

3. NETWORK OF RELATED ACTIVITIES

The principle of relatedness signals a path to this undiscovered area (Hidalgo, Klinger, Barabási, & Hausmann, 2007). It says that a relation exists between two or more activities (e.g. products, industries, or research areas) whenever they require similar knowledge or inputs (Hidalgo, Klinger, Barabási, & Hausmann, 2007).Some specific factors can describe the relatedness between a pair of services, hence likely to be produced in tandem. Analogously, un-related services are less likely to be co-produced.

Furthermore, relatedness of economic structures and knowledge highly determine the future path of industrial, technological and occupational diversification (Hidalgo et al., 2007), the organizations have a tendency to move into activities that share similar knowledge and productive capabilities. And to a certain extent, the opposite can also be affirmed, that is, it's hard to diversify the service portfolio of unrelated activities. (Frenken & Boschma, 2007). The principle beneath confirms that an economy that produces cotton will probably find it much easier to add to their portfolio the production of textiles rather than robots or any other un-related activity. (Hartmann, Bezerra, & L. Pinheiro, 2019)

Therefore we access the proximity between two services by their shared knowledge and through the analysis of the probability of them being offered by the same contracted entity. Formally,

the proximity between services s and s' is the minimum of the conditional probability that a private organization has a Revealed Comparative Advantage (RCA) in both services.

The term Revealed Comparative Advantage (RCA) refers to an economic index that calculates whether a given country has advantage or disadvantage on the worldwide trade flows, in a certain area or commodity. Most countries choose to export their in house products for things they lack. A simple example can be given using a humble product, bananas. Countries like Ecuador and Hawaii detain a comparative advantage over a long list of countries on this good.

Similarly we will use this methodology to validate the level of relatedness of services provided by private companies inside the Portuguese public market. Using the symmetry of the above theory, we can define the service complexity index with services(s) on the previous definitions. We say that when a Portuguese contracted entity has a Revealed Comparative Advantage > 1 on a given service then is considered to be an effective producer of that service a. The contrary is also applied. We use this index to validate the private contracted entity comparative advantage over other operating companies in the Portuguese market (i.e. the services that each private organization offers based on the overall services provided in Portugal).

To compute proximity, we organize service data using specialization matrices (X_{cs})that summarize contract values (in Euros) of company *c* in service *s*. (e.g. medical tools, construction works denoted with the subscript s). The Revealed Comparative Advantage (R_{cs}) relates companies with their relevant offered services (i.e. the services they sell based on the Portuguese total market share).

The RCA formula can be defined has the following:

$$R_{cs} = \frac{E_{cs} / \sum_{s' \in S} E_{cs'}}{\sum c' \in C^{E_{c's}} / \sum c' \in C, s' \in S^{E_{c's'}}} \quad (1)$$

Where, the index is equal to the contracted entity offer in a certain service, $\frac{E_{cs}}{\sum c' \in C^{E_{c's}}}$ divided by the proportion of the entire space (Portugal) for that commodity$\frac{\sum_{s' \in S} E_{cs'}}{\sum c' \in C, s' \in S^{E_{c's'}}}$.

After, we define $E_{cs} = 1$ if a company has comparative advantage in a given service ($R_{cs} > 1$) on a given service if their share on the total Portuguese universe of expenditure is positive and say that all values under 1, will be defined has$E_{cs} = 0$. Matrix E_{cs} has all companies' relevant services.

It's interesting to see the diversity of services portfolio offered by each company and the ubiquity of a service as the number of companies offering such service ($K_s = \sum_c E_{cs}$), both with revealed comparative advantage.

We can now focus on proximity. The proximity between two services *s* and *s'* ($\emptyset_{ss\prime}$) is calculated through the minimum conditional probability that a company has a revealed comparative Advantage (RCA) in both services:

$$\emptyset_{ss'} = \frac{\sum_c E_{cs} E'_{cs}}{\max(K_s, K'_s)} \quad (2)$$

For example, if 12 contracted entities offer service x with RCA>1, and out of those 12, 6 of them also offer service y with RCA > 1 then the general offering probability – proximity – for service x in relation to product y is 50%.

Resulting values are referred to as density, ω_{cs} of service s in company c as:

$$\omega_{cs} = \frac{\sum_{s\prime} E_{cs'} \emptyset_{ss\prime}}{\sum_{s\prime} \emptyset_{ss'}} \quad (3)$$

Services with higher density correspond to companies' offering similar capabilities, the reverse is also applied, and lower density services are farther proximity wise.

III. METHODS AND MATERIALS

4. DATA AND INFORMATION

We rely on available data retrieved from the web portal base.gov.pt, which contains Portuguese public procurements over the years, 2008-2020. The BASE portal represents a centralized instrument that aggregates procurement information, regardless of their nature, that involves a Portuguese public institution and a third-party. This results in statistical information on national public procurement and public expenditure, in particular for drawing up the annual public reports and statistical reports to the European Commission. Although it is arguably an incomplete dataset, from the perspective of the entirety of activities private companies offer, we will use it as a proxy to access public sector information in the Portuguese Economy.

According to IMPIC, this portal manages information related to 81.88% (Direção Financeira, de Estudos e de Estratégia Instituto dos Mercados Públicos, do Imobiliário e da Construção, I.P., 2020)of all public procurements registered in the 5 available certified electronic platforms.

The information available in such datasets include data related to initial public offering (e.g., issue date, upload date, duration, and involved institutions), financial info (e.g., contract price value (in Euros), final contract values), and other important information (e.g., tender applicants, and service classification provided by the CPV which is described in the Common Procurement Vocabulary).

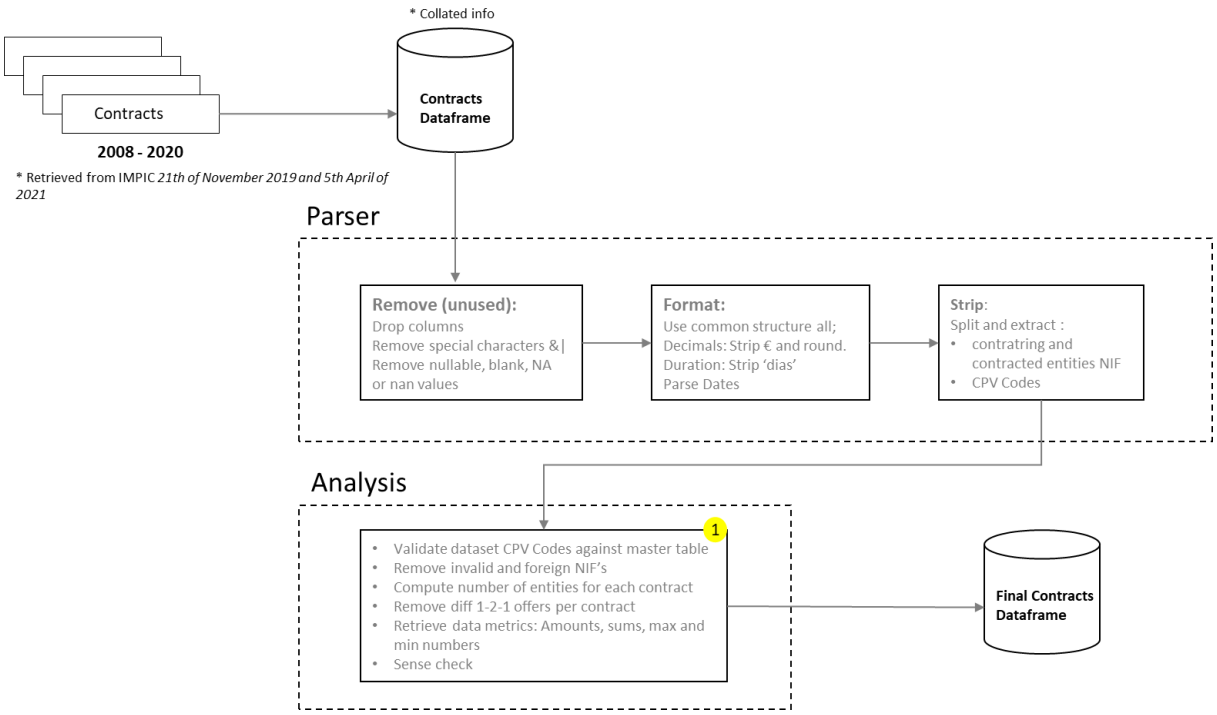

Figure 2 | **Contract data Diagram,** allows for a graphical visualisation on the theoretical process of contracts until final image.

The sourced data was transferred to a two-dimensional heterogeneous tabular data structure that allows for easy arithmetic operations (rows and columns) to ease dataset manipulation, in python. Furthermore, we remove any contract that doesn't contain essential information for the purpose of this thesis (incorrect CPV and NIF values, foreign NIF's, records with negative, null or missing contract price values). We parse and strip raw key information, like CPV (Code and description), duration, dates and contract value to remove any irrelevant wording or information that would difficult our analysis.

To simplify our analysis, we exclude any contracts that given their nature had more than one to one (see Figure 2 | **Contract data Diagram**) contracted or contracting entity, studying only on a one-to-one company basis.

The resulting data includes information about 1.048.576 tenders/procurement contracts (*retrieved data in 21th of November 2019 and 5th April of 2021(year 2019 and 2020*), ranging from 2008 to 2020 and total contract amount of 60 Million € (including taxes – 60,505,772,405) and 109721 distinct private companies.

Has part of the parsing and dataset correctness checks we removed the equivalent of 1.2% of contracts.

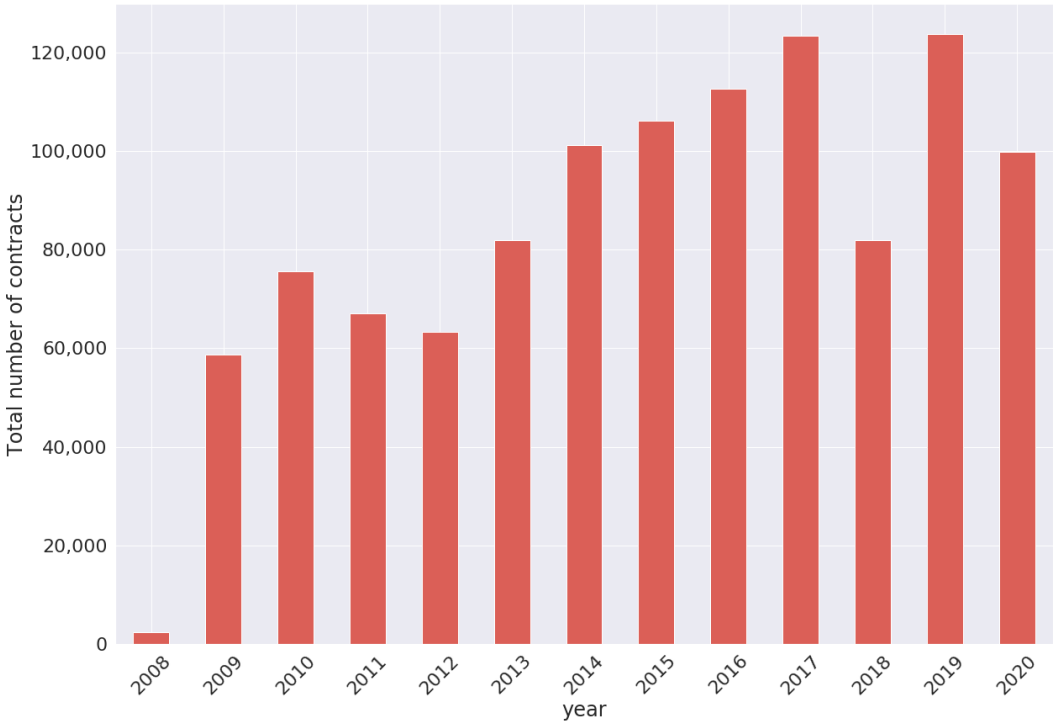

Figure 3 | **Yearly Contracts distribution,** this images show the evolution of total contracts registered in Portuguese digital platforms grouped by year. We observe that for 2011, 2012 and 2018 we have a decrease in the number of contracts performed. This can be somehow explained by the financial crisis momentum lived during this period, although it is outside the scope for this thesis to further analyze.

To perform a deep analysis and visualize central data tendencies we plot a histogram, containing information on how contract values are distributed. The below Figure 4, plots the distribution of continuous logarithm contract value observations against the density variation. It shows that the majority of observations values range between 3 and 5, following a normal distribution.

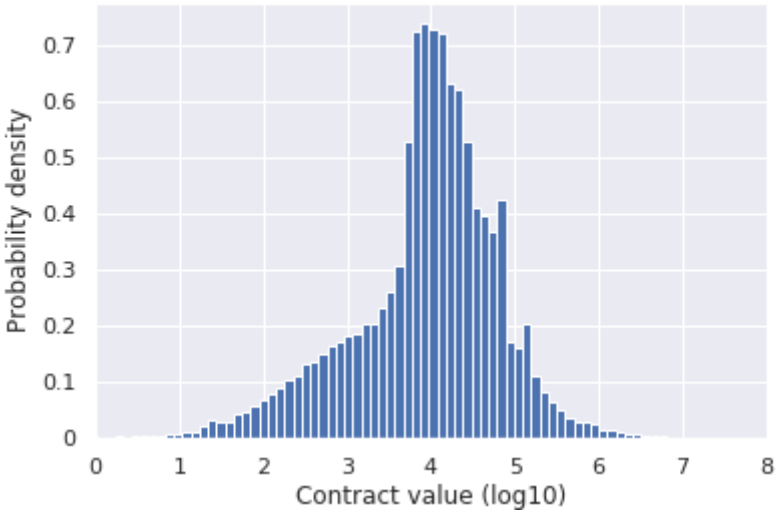

Figure 4 | **Cumulative contract value distribution** we can visually exploit how Portuguese contract values distribute. We perceive it follows a normal distribution, meaning that most contracts (>0.7) have average contract values.

Although this dataset can be exploited from several perspectives we'll be focusing on the CPV proximity analysis that define the procurement codes until category level, this will allow us to obtain an optimal CPV level to study the evolution of the type of supplies, works or services forming the subject of contract for each private company.

IV. RESULTS

5. COMMON PROCUREMENT VOCABULARY

The common procurement code (CPV) classification system allows for a unique subject definition used by both contracting and contracted companies while forming public procurement agreements. The level of detail used is key to ensure not only a proper classification and to avoid ambiguity which allows for a higher number of bidders while guaranteeing transparency.

Historically, this classification system was based in service expert judgement. Our analysis will offer an alternative structuring of services that is based in data from the revealed activity patterns of companies. We shouldn't expect to see a major mismatch between the data-driven representation and the traditional classification, but the former will present a more accurate representation of the proximity/overlap between services and products, in the service space.

The CPV structure is composed by a main vocabulary that standardizes references used to describe the subject of contracts (9454 terms that list goods, works and services broadly used on procurement) (European Comission, 2008). It is composed by 9 characters (8 numbers and a control character). The first two digits identify the 45 divisions (**XX**000000-Y), whereas the following 6 determine the classification level - composed by groups, classes, categories and sub-categories - (SIMAP) and add precision(see Table 1 | **CPV description**). (European Comission, 2008)

Table 1 | **CPV Example**

Levels	**Common procurement vocabulary Level Name**	**Code Example**	**Description**
1	Division	**35**000000-4	Other transport equipment
2	Group	35**1**00000-**5**	Ships and boats
3	Class	351**1**0000-**8**	Ships
4	Category	3511**2**000-**2**	Ships and similar vessels for the transport of persons or goods
5	Sub-category	35112**100**-**3**	Cruise ships, ferry boats and the like, primarily designed for the transport of persons
6		35112**110**-**6**	Ferry boats
7		35112**180**-**7**	Cruise or excursion boats n.e.c

Table 1 | **CPV description** contains an example to better understand how contracts are typified using CPV vocabulary. The above shows a valid code for any contract performed with a public sector where the subject of such contract would be buying transport equipment (boats**)** (European Comission, 2008)

We start by removing any contracts with values below 500 euros to reduce data ambiguity and noise and to better heighten the dataset.

In the first approach, we sought to obtain an overview of the accuracy of the CPV. We investigated the extent to which CPV codes contain information until a certain level. And computed optimal CPV selection level through the use of normal distribution to perceive which granularity would provide the optimal data stage for the trade-off between, data resolution and data loss.

With 7 distinct levels (e.g. Level one, first two characters; Level 2, first three characters) we observed that each record represented by a contract had the first two characters (Level one), properly defined (see Figure 5).

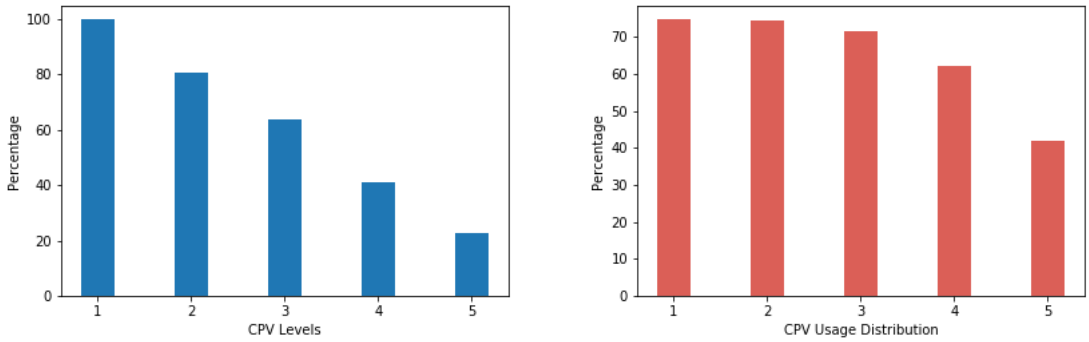

Figure 5 | **CPV coverage and usage.** The CPV usage shows 100% coverage at Level 1, it means that all retrieved contracts have the two first characters properly defined in their subject. We observe that this tendency diminishes at each level which reveals an increasingly poor CPV categorization, either by vocabulary unfamiliarity or lack of CPV coverage for their contract subjecting. CPV usage also follows a declining trend, showing that only 70% of all CPV codes are used to classify contracts. At level 5 we can see that it decreases significantly, a possible reason for this can be given by the poor CPV usage found at this level.

On a second iteration, we performed the CPV coverage analysis by comparing the list of current CPV's used in our dataset against the full list of CPV codes, which remain mostly unchanged for the first three levels (Level 1: 74.81%, Level 2: 74.33%, Level 3: 71.52%) (See Figure 5), but highly decreases from Level 6 onwards.

In a nutshell, better data resolution could amount for the reduction of errors while analyzing contracts but on the other hand it can also mean that more and more data is loss, due to accuracy incorrectness, which lead us to conclude that category level (Level 2: first three digits) is the optimal balance, has we'll still be able to fully differentiate contracts whilst maintaining enough data to analyze.

6. PROCUREMENT SERVICES PROXIMITY SPACE

After proper CPV selection we structure data using the specialized matrix (M_{cs}), which allows to individually interpret the share of contracted entities and their offered services (E.g. retrieved data such has related to laboratory equipment's has average contract value of 8.602.892, 21 €).

Our goal is to involve the measure of proximity between the different services, encoded by the CPV. To measure the proximity between two services we compute the probability, p (S_2| S_1) that a company selling service, S_1, is also likely to sell other service, S_2. Formally, the proximity between services S_1 and S_2 is the minimum of the conditional probability that a private organization has a Revealed Comparative Advantage (RCA) for both services. RCA is used to identify which services a company is selling/offering, given the size of that service market and the portfolio of services sold by such institution.

We create the service space from the square proximity matrix containing 316x316 entries (Level 2 combinations), that represent a particular service and where pairwise diagonal values are composed by infinite values (See Figure 6). This symmetric matrix is sorted by CPV code and each element represents the pairwise proximity between two services. We can observe many empty or 0 elements which belong to un-relatable services(less similar).

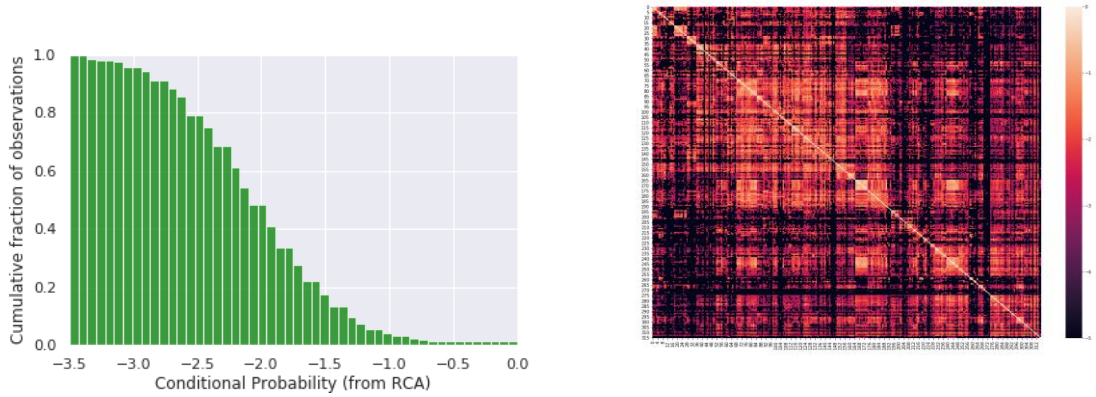

Figure 6 | **Cumulative RCA distribution and service proximity heatmap.** We observe from the left image that relevant RCA's (RCA >1) are sparse in our space . On the right we plot a data visualization technique on how data proximity is clustered in the service space. Represented by a matrix of (316x316) services where higher proximity values are represented by darker colors, shows the frequency distribution of proximities.

Represented in Figure 6 is the cumulative distribution of weights, that is, relatedness in the entirety and observe a heterogeneous distribution showing that the vast majority of links have marginal weights and only few are composed by strong connections. For instance, a proximity of 0.6 between two services would mean that there is a 60% chance that a company with a

Revealed Comparative Advantage in one service has RCA in both services (Hidalgo et al., 2007).

Figure 7 shows the Portuguese service space visualization based on the proximity matrix, which is the connecting network of similar services ($\emptyset_{ss\prime}$) and depicts which services have higher density (ω_{cs}) values, hence more relevant to this universe. This will help to retrieve insights on the dynamics of services, and because our space contains so many weak connections we use the minimum spanning tree (MST) algorithm to generate the network "skeleton", which maximizes the sum of proximities (Hidalgo, Klinger, Barabási, & Hausmann, 2007), and show relevant links.

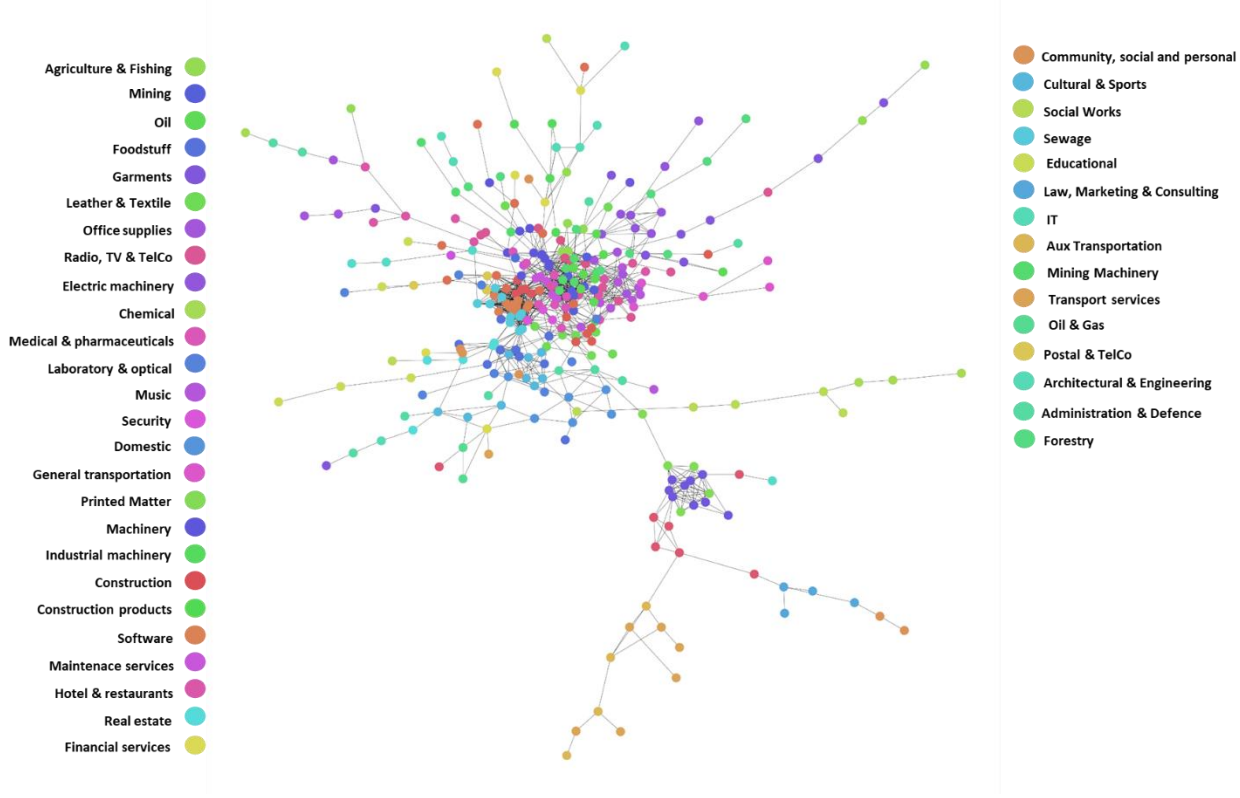

Figure 7 | **Portuguese Procurement Proximity Network (3PN)** highlighted over 2018-2021 period with relevant services (RCA >) 1. The node coloring corresponds to each one of the 45 Level 1 categories. Most close services are referenced in the right legend.

There are diverse visualization techniques, for the service space we use the Kamada-Kawai layout, used in drawing undirected graphs (Tomihisa & Satoru, 1989). This algorithm attempts to position nodes so that their Euclidean distance in the space is as short as the path distance between them. Although Kamada-Kawai is slower and computationally expensive for large networks, this doesn't represent a problem in our space.

We can definitely visualize proximity in some sectors, as density computes the distance between a given service and all related services. Relatively high density values account for a diversified economy - highest degree of similarity and hence relatedness to the providing capabilities of companies -and are key in predicting the probability that a location –Portugal - increases or decreases its specialization in an activity.

This overall network representation and the individual analysis of each service category allowed to visually acknowledge that services represented inside each category level are tendentiously more close to other similar services, which indicates a good CPV characterization, in practice.

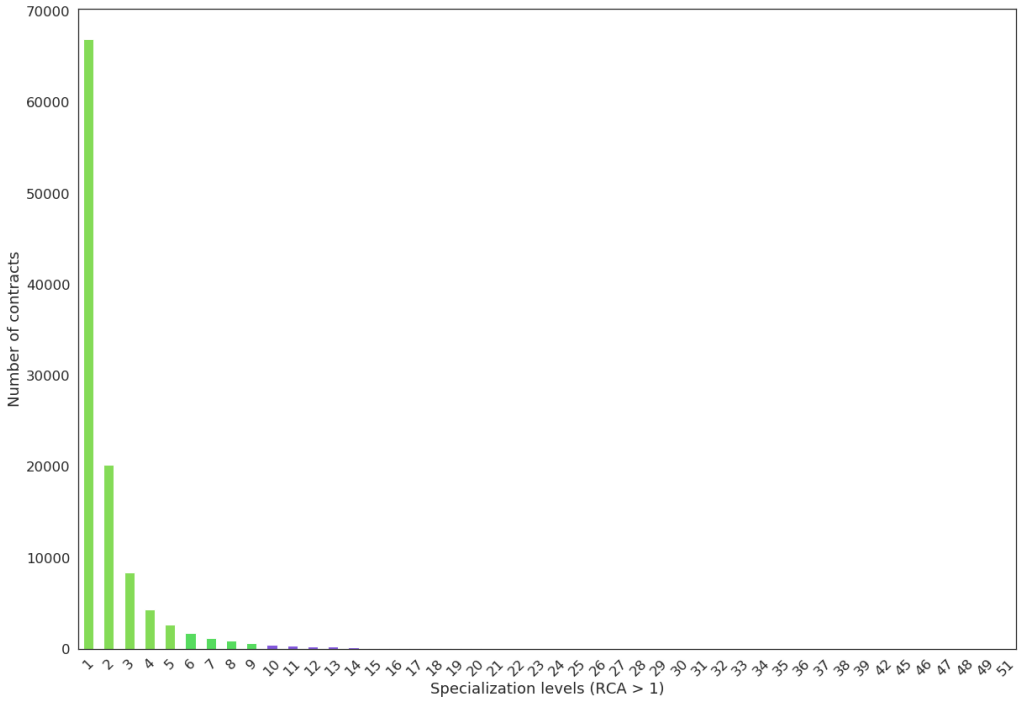

Figure 8 | **RCA Specialization Diagram** this figure shows the level of RCA distribution between the entire Portuguese procurement proximity network(3PN) and denotes that the majority of companies is not really diverse and offer only one specialized service.

Network representation let us observe not only the structure but also other covariates. We want to differentiate which services better contribute to higher contract values and where they are located inside the network. For this, we scale service node sizes proportionately with their contract values – or money involved in a specific service category - , and use logarithmic node size scaling due to the dispersive values of contracts. Again, we painted the network using the service classifications at Level 1.

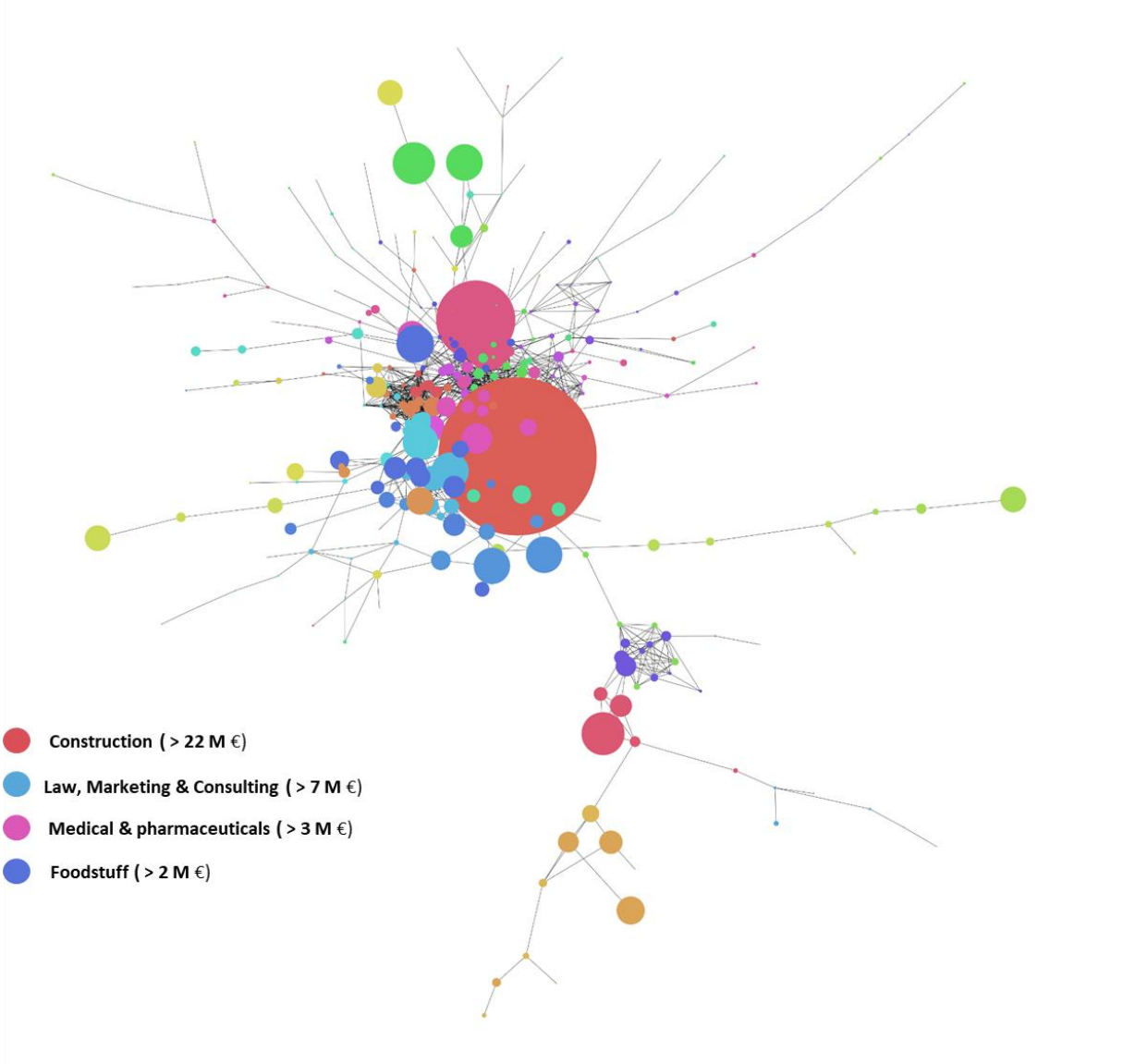

Figure 9 | **Contract valued network.** Final version of the service space where we introduce a new dimension, that is, contract amount values. We observe that red nodes on the far left are represented by the higher contract values and are related to the Construction works service. We see which services contribute further to higher amounts and this are represented in the legend

On average, contract values seem to be small. With some exceptions for services that also proven to be more category related. In this network, the nodes color corresponds to level 1 categories has it would be impossible to plot all 382 different node colors has it will be visually overcrowded and difficult to extract insights from. Are high contract value located in particular parts of the service space? We observe that the largest nodes position are in the center and network ends. And the best payed contracts, composed by construction services (22.664.516.144 €), medical equipment's (7.260.024.973 €) and business services, which include law, marketing and consultancy (3.105.048.378 €) and the least payed in purified water (9.979.158 €).

We then try to identify how cohesive is the Portuguese service space as an entire, either by node proximity inside a category or inside each company.

7. SERVICE COHESIVENESS AND CLUSTERING

Network cohesion and clustering are key to grasp how networks shape communities or even form the basis of group identity, among others (Moody & Coleman, 2015) In a first iteration, we seek to measure the cohesiveness of Portuguese service space to answer two important questions, do cohesive services are more competitive and generate more income? And secondly try to infer which are the top core offerings and private company's capabilities. To answer these two questions we start by calculating the top most and least cohesive services and companies in our space.

We organize data using a matrix that connects 109.719 private companies and 316 services. The pair value is represented by the contract amount spent for each service and company.

The service cohesiveness is calculated through a subset of data from the original Portuguese universe. These dynamically created subsets of information contain all service nodes grouped by category, Level 1. Afterwards, we compute the average sum of distances, from the proximity matrix, between all nodes (n to n-1) in that category. Results are shown below. (See Table 2)

Table 2 **Rankings of service cohesiveness**

Rank	Category service cohesiveness Service Code and Description	Number of nodes	Average Proximity (μ = 0,072)	Contract value
1	30 - Office and computing machinery, equipment and supplies except furniture and software packages	3	0.2703	822.025.440,00 €
2	48 - Software package and information systems	10	0.2346	774.608.213,00 €
3	32 - Radio, television, communication, telecommunication and related equipment	5	0.1927	355.225.670,00 €
4	45 - Construction work	6	0.1355	22.664.516.144,00 €
5	33 - Medical equipments, pharmaceuticals and personal care products	5	0.1348	7.260.024.973,00 €
6	41 - Collected and purified water	2	0.1166	9.979.158,00 €
7	72 - IT services: consulting, software development, Internet and support	10	0.1117	1.998.711.250,00 €
8	31 - Electrical machinery, apparatus, equipment and consumables; Lighting	8	0.1058	442.239.056,00 €
9	64 - Postal and telecommunications services	3	0.1048	408.336.947,00 €
10	39 - Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products	7	0.1040	531.411.728,00 €
11	03 - Agricultural, farming, fishing, forestry and related products	5	0.1031	125.328.341,00 €
12	38 - Laboratory, optical and precision equipments (excl. glasses)	10	0.0995	289.449.478,00 €
13	15 - Food, beverages, tobacco and related products	10	0.0984	688.076.088,00 €
14	18 - Clothing, footwear, luggage articles and accessories	9	0.0959	146.820.032,00 €
15	16 - Agricultural machinery	8	0.0958	36.380.808,00 €
16	09 - Petroleum products, fuel, electricity and other sources of energy	4	0.0932	2.627.833.089,00 €
17	90 - Sewage-, refuse-, cleaning-, and environmental services	6	0.08288	2.596.099.759,00 €
18	37 - Musical instruments, sport goods, games, toys, handicraft, art materials and accessories	5	0.0800	74.540.788,00 €
19	63 - Supporting and auxiliary transport services; travel agencies services	4	0.0731	292.697.275,00 €
...	...	...	...	...
20	50 - Repair and maintenance services	9	0.0648	2.197.638.806,00 €
21	71 - Architectural, construction, engineering and inspection services	9	0.0623	2.011.723.431,00 €
22	42 - Industrial machinery	9	0.0608	295.414.536,00 €
23	44 - Construction structures and materials; auxiliary products to construction (excepts electric apparatus)	9	0.0586	591.242.367,00 €
24	55 - Hotel, restaurant and retail trade services	7	0.0573	1.898.055.612,00 €
25	22 - Printed matter and related products	9	0.0518	224.611.949,00 €
26	70 - Real estate services	4	0.0505	25.154.801,00 €
27	79 - Business services: law, marketing, consulting, recruitment, printing and security	10	0.0489	3.105.048.378,00 €
28	24 - Chemical products	8	0.0461	194.447.181,00 €
29	73 - Research and development services and related consultancy services	5	0.0455	190.542.812,00 €
30	66 - Financial and insurance services	5	0.0445	715.859.757,00 €
31	35 - Security, fire-fighting, police and defence equipment	9	0.0380	274.288.977,00 €
32	34 - Transport equipment and auxiliary products to transportation	9	0.0363	1.189.387.827,00 €
33	19 - Leather and textile fabrics, plastic and rubber materials	7	0.0338	45.535.127,00 €
34	85 - Health and social work services	4	0.0334	575.601.368,00 €
35	75 - Administration, defence and social security services	4	0.0248	199.621.553,00 €
36	80 - Education and training services	7	0.0227	319.267.077,00 €
37	92 - Recreational, cultural and sporting services	8	0.0221	737.502.962,00 €
38	43 - Machinery for mining, quarrying, construction equipment	9	0.0207	63.545.683,00 €
39	60 - Transport services (excl. Waste transport)	7	0.0194	1.312.980.044,00 €
40	51 - Installation services (except software)	10	0.0192	141.351.393,00 €
41	14 - Mining, basic metals and related products	9	0.0174	77.658.109,00 €
42	76 - Services related to the oil and gas industry	7	0.0168	45.460.758,00 €
43	65 - Public utilities	6	0.0164	750.278.626,00 €
44	77 - Agricultural, forestry, horticultural, aquacultural and apicultural services	10	0.01494	521.136.367,00 €
45	98 - Other community, social and personal services	6	0.00905	658.112.667,00 €

Table 2 | **Top service cohesiveness** we observe from the entirety of the dataset that top ranked categories have tendentiously higher contract values than other lower dense ones.

Services with higher density values presented in Table 2, are the closest – proximity wise – and the most specialized offerings by companies. We can further analyze to the IT services category (rank #7, Table 2Table 2). It contains ten different nodes – internet, software programming and consultancy services amongst others–with average proximity of 0.1117 and accounts for above contract average value.(30.252.886.203 €) While comparing to the least cohesive services they

show a tendency for higher contract value amounts. Higher ranked services sum 42.144.304.237€ against 18.361.468.168€. One could argue that this significant difference comes from the total values found in the construction category, but if we remove this heavy weight category from the equation, still remain higher for the top ranked categories (green color). Services included in community and social activities include six nodes - ranging from religious and domestic - have lower density values and are therefore more unrelated to the country's core of offerings and private sector capabilities.

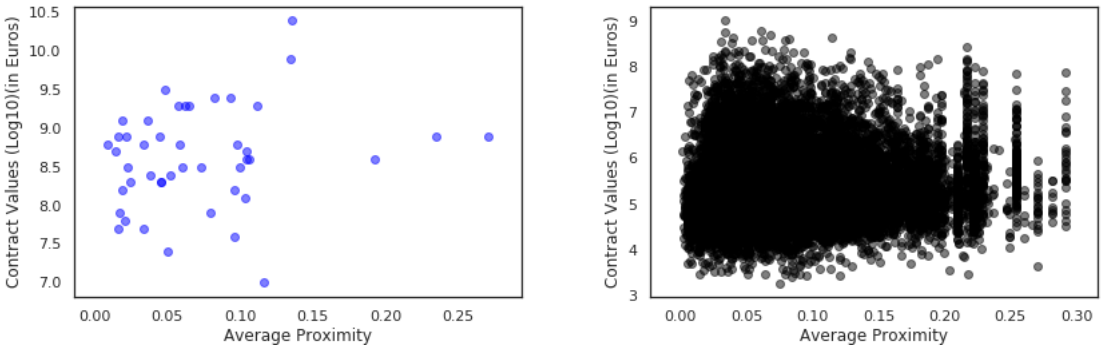

Figure 10 | **Service and companies cohesive correlation plots** On the left image we can see service proximity distribution and their contract values. We cannot correlate any of the two variables that is, contract value and average proximity, since these don't seem to follow any pattern, negative or positive. On the right image, we see the 22534 company's average proximity correlated with their contract values.

Furthermore we can observe that services with higher proximity rates are drawn closer to each other. For the food and beverages level 1 category we can see that all 10 nodes are deeply connected whilst for community and social services they tend to be more dispersed. (See Figure 11)

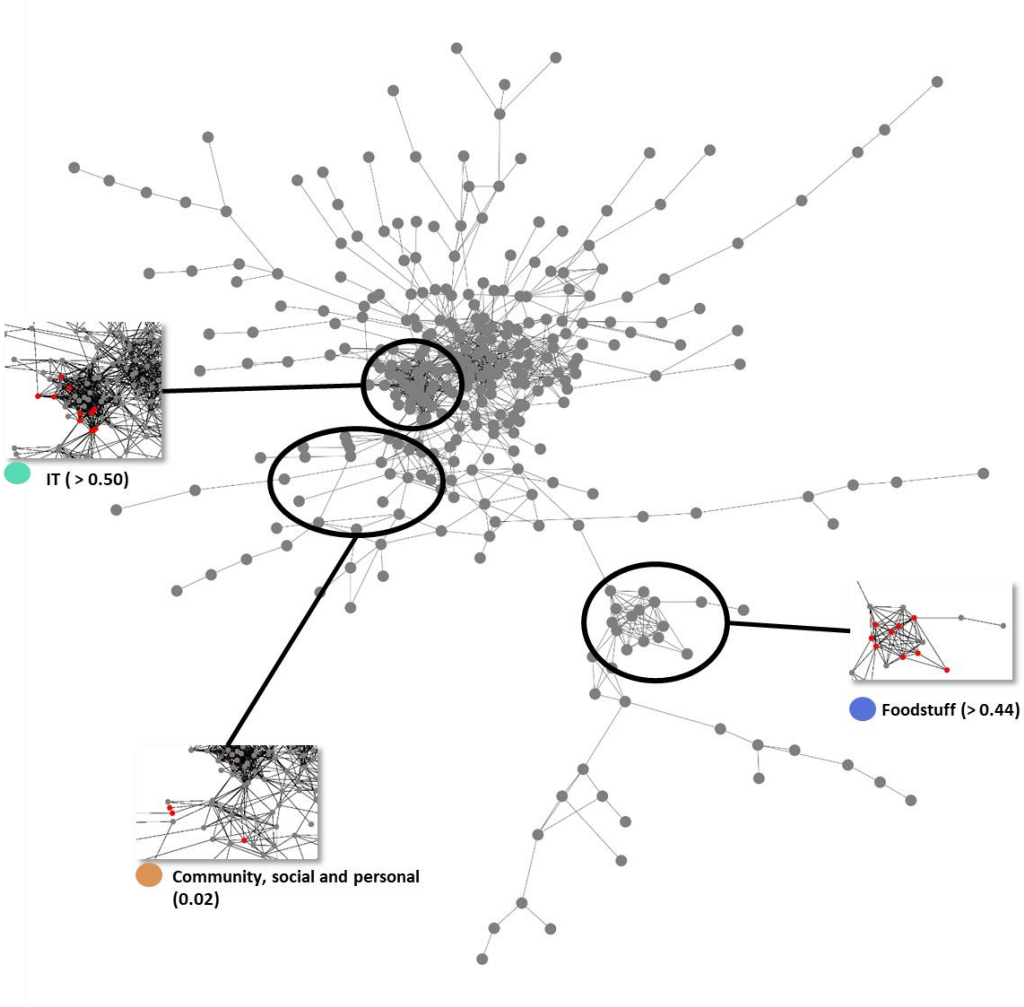

Figure 11 | **Cohesive and dispersed nodes.** We highlighted three sections to visually demonstrate how the different cohesion levels are plotted Observing that for IT and foodstuff categories nodes are significantly closer (see red nodes representation) than for the community category, which has relatively lower density (only 0.02)

For the second part, we analyze the cohesion of offered services by each company. We filter the binary matrix (RCA) to retrieve companies whose services had revealed comparative advantage (RCA>1) at least in three different serviced offered (three nodes). The sample has a reduced size of only 22534 records from the total universe of companies. We seek to validate cohesion of each entity separately by calculating their average proximity to the existent nodes (services), which allows for a better insight on their distribution – clustered versus dispersed.

Table 3 **Rankings of contrated entities cohesiveness**

Rank	Contracted entities cohesiveness Contracted entity NIF and name	Number of Nodes	Average Proximity	Contract value
8	503047201 - pharmaceutical related company	3	0.2915	76.747.147,00 €
7	502801204 - pharmaceutical related company	3	0.2915	29.383.378,00 €
10	503550558 - pharmaceutical related company	3	0.2915	8.515.848,00 €
5	501172114 - pharmaceutical related company	3	0.2915	4.743.680,00 €
9	503538108 - pharmaceutical related company	3	0.2915	1.451.889,00 €
3	500174245 - pharmaceutical related company	3	0.2915	669.169,00 €
6	502595302 - pharmaceutical related company	3	0.2915	333.423,00 €
2	500061246 - health institution	3	0.2915	100.754,00 €
4	500609985 - pharmaceutical related company	3	0.2915	43.773,00 €
1	183558839 - Humanitarian related company	3	0.2915	31.899,00 €
...	...	...	...	...
22523	513288791 - engineering related company	3	0.0029	164.250,00 €
22524	508988306 - Printed matter related company	3	0.0028	53.693,00 €
22525	500075611 - Food, beverages related company	3	0.0025	60.172,00 €
22526	245851704 - community and social related company	3	0.0025	17.700,00 €
22527	503481670 - inspection services related company	3	0.0024	332.250,00 €
22528	501751564 - Agricultural related company	3	0.0024	55.244,00 €
22531	504807692 - environmental services related company	3	0.0023	120.031,00 €
22533	510951279 - Food, beverages related company	3	0.0018	158.194,00 €
22534	501789650 - Food, beverages related company	3	0.0016	30.671,00 €
22532	501048090 - - Humanitarian related company	3	0.0011	1.397.258,00 €

Table 3 | **Top 10 entity cohesiveness** we observe that most of the top ranked companies are related to the pharmaceutical industry. This is only natural since medical and pharmaceuticals category detains fifth place in service cohesiveness(0.134).

For the total amount of 22534 contracted entities as per the above conditions 74 %(1673) have widely dispersed services (average proximity below 0.1) and only 4% (887) contain medium proximity distribution (above 0.2).

Which leads to conclude that most companies tend to differentiate their services from their core offers which might imply their broader offerings whilst the remaining offer related services – more specialized in specific areas.

Do companies that offer more cohesive services generate more money? To understand we inspect three of the most well known and most relevant Telco companies e.g., Company X, Y and Z in the Portuguese market and observe that they offer a diverse amount of services (number of nodes), 45, 15 and 26 respectively(X, Y and Z).

Table 4 **TelCo Comparison**

Rank	Common procurement vocabulary Company Names	Number of services	Average Proximity	Contract Amounts
#1	X	45	0.05415733333333333333333333333	397.927.185,00 €
#2	Y	15	0.05704857142857142857142857143	67.137.861,00 €
#3	Z	26	0.06553741538461538461538461538	55.763.416,00 €

Table 4 | **TelCo Comparison** allows for a deep dive into the three most relevant television and telecommunication providers.

We cannot conclude for this particular case that higher proximity rates determine higher contract shares, solely. We denoted that company X offers a major number of services while maintaining a relatively good proximity between their offers, which could be a good indicative of higher contract shares.

8. SERVICE SPACE COMMUNITY ANALYSIS

Visually grouping ordinary objects into categories can present insights and evidence informational patterns to the reader. (Radicchi, Castellano, Cecconi, Loreto, & Parisi, 2004) In network science a community represents the likelihood of a group of nodes connect to each other in opposition to other nodes in different communities, form locally densely connected sub-graphs. (Barabási, 2016).

The concept of community is common and can be linked to other definitions like module, class, group, cluster, others (Radicchi, Castellano, Cecconi, Loreto, & Parisi, 2004). Modularity is often considered as a property and be defined has the degree within a cluster minus the expected degree - or number of nodes - within other clusters. This forms highly dense compartments that can be decoupled into separate groups, called communities (Kharrazi, 2019). High modularity can be defined has higher node connections inside a specific cluster (intra- community connections) and less outside the cluster (Fan, 2020).

We use the Louvain methodology algorithm to recursively detect communities, that uses modularity optimization and runs on time complexity O(n log n), n being the number of nodes – services - hence better suited for large networks. Other community detection methods might prove inefficient due to time complexity (Fan, 2020).

We analyze the entirety of the Portuguese service space has a set of communities and try to profile clusters to validate service relatedness within – that measure service space homogenous – and describe distinct sub-populations.

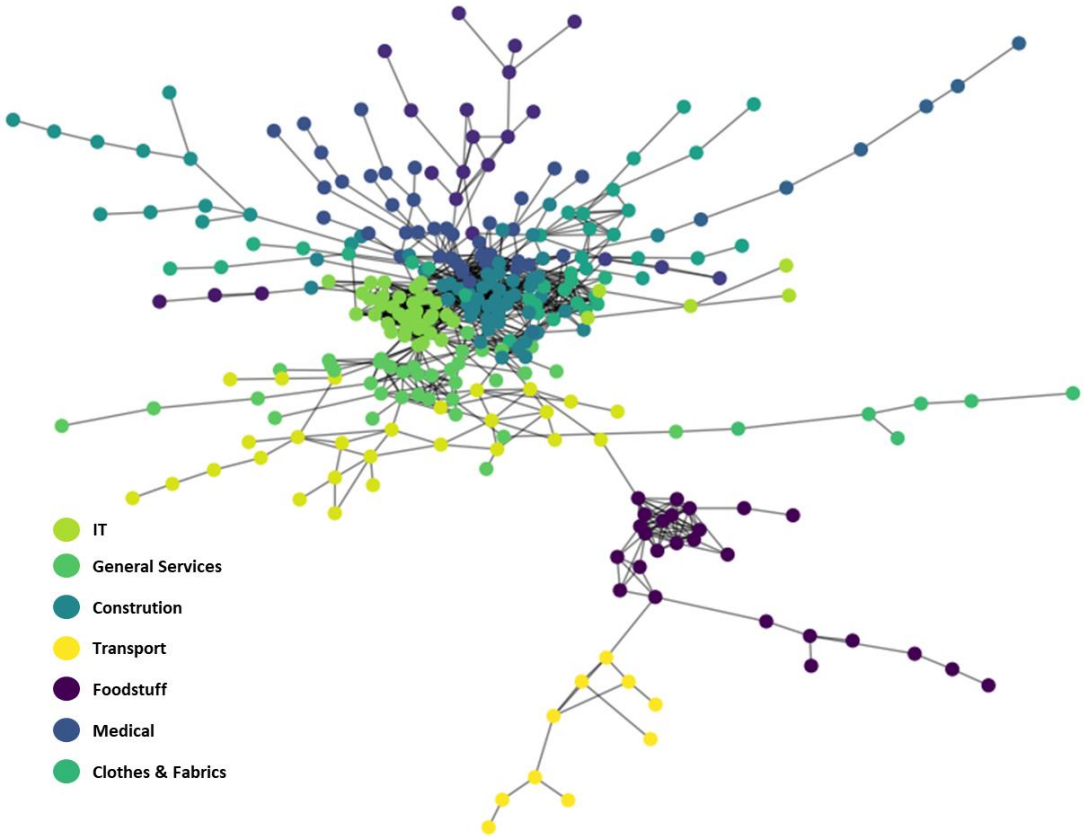

Figure 12 | **Service Community.** In this image we show the most relevant – node wise - communities in the service space. Construction and IT lead with 50 and 38 nodes, respectively. Construction and medical communities lead on total contract values.

We can see 17 different communities. We seek to profile each cluster to find undiscovered relationships between nodes within. We group similar observations and a good example would be to have similar or interdependent categories, e.g. food and agricultural. Below is the informational list of the most relevant (number of nodes) communities.

Table 4 **Cluster Profiling**

Clusters	Analysis Service predominance	Number of services	Total contract value
Foodstuff	34% - Food, beverages, tobacco and related products 26% - Hotel, restaurant and retail trade services	26	2.700.682.781,00 €
Oil & Gas	26% - Petroleum products, fuel, electricity and other sources of energy 26% - Services related to the oil and gas industry	15	3.198.836.362,00 €
Medical	24% - Laboratory, optical and precision equipments (excl. glasses) 13% - Medical equipments, pharmaceuticals and personal care products	37	7.906.627.500,00 €
Construction	16% - Construction structures and materials; auxiliary products to construction (excepts electric apparatus) 16% - Electrical machinery, apparatus, equipment and consumables; Lighting 12% - Repair and maintenance services 8% - Construction work	50	27.439.234.756,00 €
Clothes	33% - Clothing, footwear, luggage articles and accessories 16% - Leather and textile fabrics, plastic and rubber materials	24	1.694.112.934,00 €
General Services	21% - Business services: law, marketing, consulting, recruitment, printing and security 16% - Architectural, construction, engineering and inspection services	37	6.910.362.274,00 €
IT	26% - IT services: consulting, software development, Internet and support 26% - Software package and information systems	38	4.833.457.112,00 €

Table 5 | **Cluster Profiling.** We use this technique used to describe data to get more insights on how services are grouped. This table only shows the larger service communities(node wise). We can see that construction is a major group composed primarly by constructions and all related structures and materials.

We conclude that a highly diverse service portfolio inside each community, varied and unrelated, would probably indicate poor CPV classification. Since most related services would not be observed together. Similarly the opposite can also be said. The computed average modularity is 0.672 which accounts for a medium modularity score ensuring that groups as observed are distinct. (Moody & Coleman, 2015)

We can observe that node distribution varies significantly from metal community cluster containing 3 services whilst construction sums 50 nodes. On the previous chapter we already noted that construction services tend to have higher values, so it is only natural this should detain the largest contractual values.

Commonly, foodstuff is a fairly simple and easy to explain example, one would immediately think that these two are somehow correlated and densely connected, so naturally it's possible to observe this behavior in the community. Parallel, medical and laboratory equipment's share some similarities to the human eye, which are also densely connected.

The majority of the clusters seem to exemplify a good classification system. Some examples - Metal and Mixed clusters, both containing 3 services each - have no predominance services which indicate space for improvements in term of the deviations found in the our space.

V. CONCLUSION

This thesis has measure the proximity of portfolio activities in the Portuguese universe to the public sector. Provided further insights on how these private companies relate their services to better position on the market and benefit from their offerings. It uses an economic growth methodology applied to a sample of 45 services during 2008-2020 to operationalize the service space and to identify some unknown tendencies to this date.

We start by analyzing the optimal level for CPV selection, and conclude that although better data resolution could mean for error reduction while analyzing the purpose for contracting, it could also mean a lot of data is loss, due to incorrectness. We found that level 2 presents the optimal trade-off between data loss and accuracy. We then observe a heterogeneous distribution on the Portuguese procurement proximity network link weights and that similar activities seem to be graphically closer to one another.

We then turned to study the cohesiveness of services and companies to relate this measure with greater incomes. We found some differences in term of average contract values, especially for less cohesive services which could potentially have higher amounts if denser, that is, more related. Although we were not able to find a correlation pattern between average proximity and contract value. On the cluster profiling analysis, we conclude that current CPV classification system seems to fit Portuguese private company's needs, with few exceptions to marginal services – Metal and Mixed clusters – which do not have any predominance service and indicates space for improvements on CPV classification, as per what discovered in the Portuguese procurement proximity space.

Although this thesis is fairly incomplete to understand the completeness of the operating service space, it shares some important answers and it can serve as basis for other works. One of which could lie on the evolution of service portfolio diversification and their relation with economic growth and service resilience, how Portuguese companies and to some extent to each areas are they are evolving. Deriving new indicators to a more sustainable, innovative, transparent, and competitive market and measure any deviation from this relationship which can be predictive of future growth.

Furthermore, it would be of upmost value to analyze the impact of Portuguese economic geography and service diversification to calculate the impact of globalization (e.g. spatial distribution of the physical address of private companies). Studying the service space with

regards to smart specialization theories would identify possible strategic areas base on place-based economic strengths and to define clear priorities for knowledge-based investments, focusing on growth supported by entrepreneurial resources.

Lastly, to study and analyze fraud activities in the Portuguese procurement space that could have significant consequences in the economic, social and political society, to safeguard loss of billions of euros every year. (Lyra, Curado, Damásio, Bação, & L. Pinheiro, 2021)

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